NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Analytical Capabilities at NERC

Modeling & System Analysis Initiatives

University of Tennessee Knoxville Seminar – October 2016

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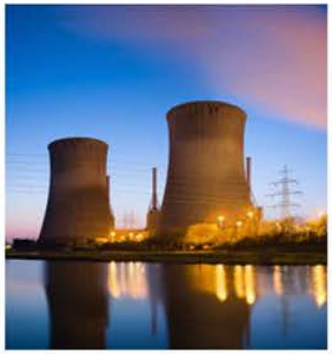
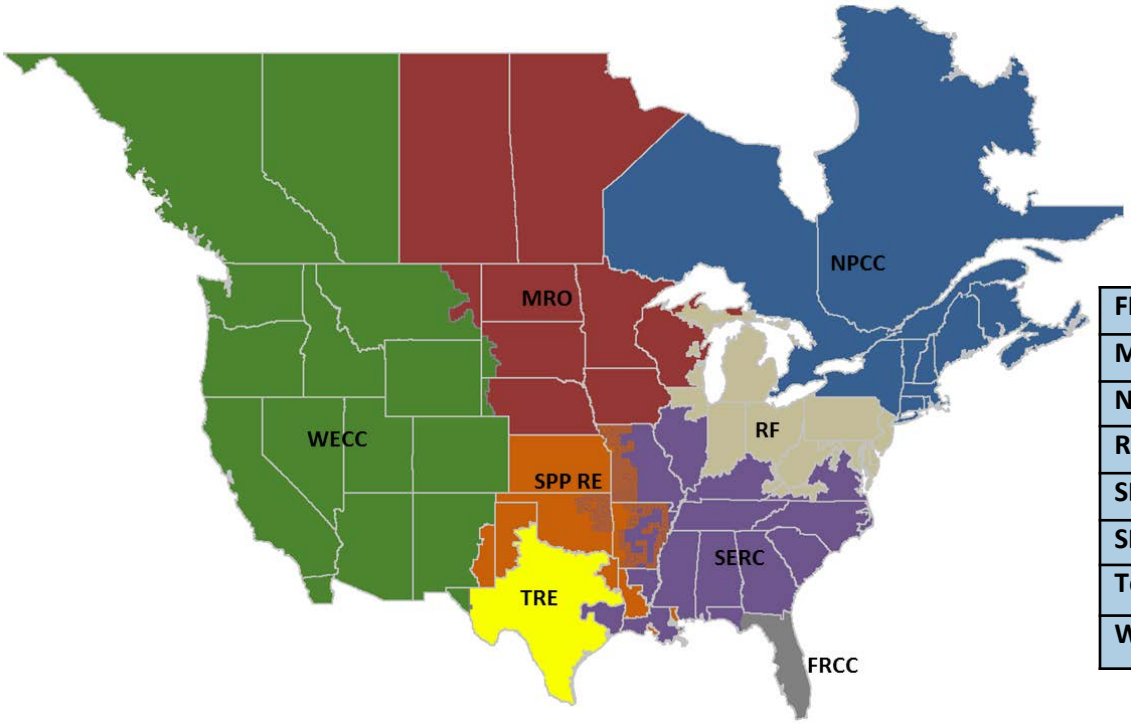
North American Electric Reliability Corporation

RELIABILITY | ACCOUNTABILITY

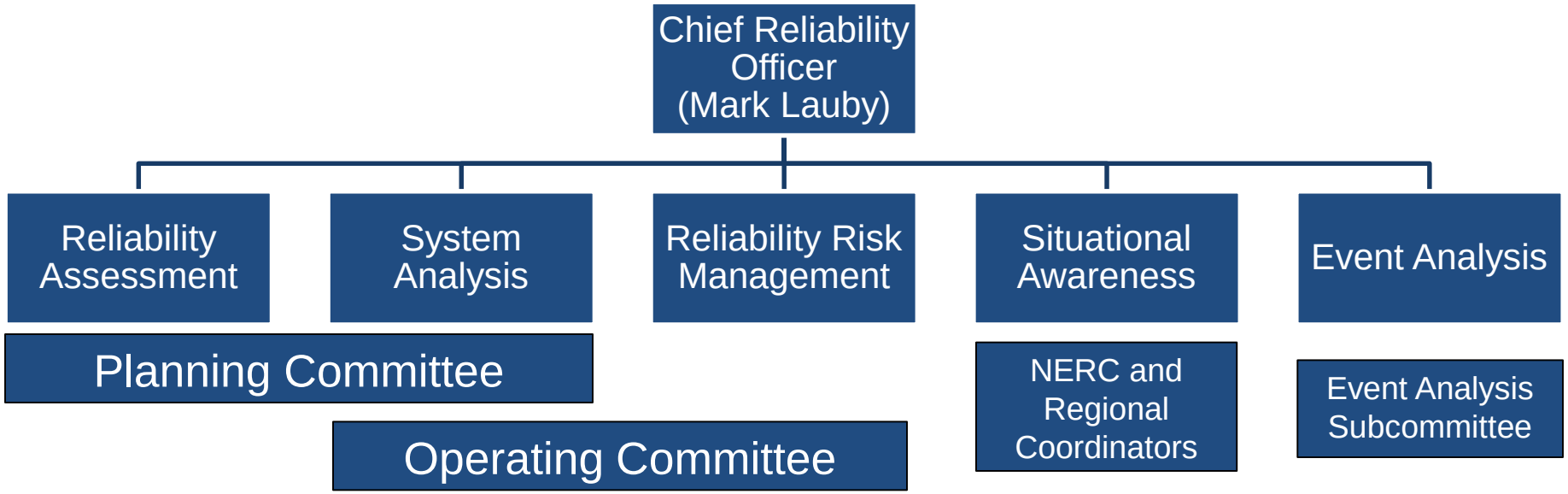
NERC Overview

- NERC Pillars of Success:
  - **Reliability**: address events and identifiable risks
  - **Assurance**: assure reliability to public, industry, and government
  - **Learning**: promote continuous improvement, lessons learned
  - **Risk-Based Approach**: focus attention and actions on most important issues



FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
SPP RE	Southwest Power Pool Regional Entity
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Technically-Focused Groups at NERC



- Periodic Assessments
- ES&D / EIA-411
- Special Assessments

- Interconnection-wide Analysis
- Model Validation
- Event Forensics
- BES Definition Exception Requests

- NERC Alerts
- Lessons Learned

- Real-time information sharing
- Daily RC calls
- Government Coordination

- >Cat2 Event Analysis
- Root cause and cause coding
- Event trending

Ramping Up NERC's Analytical Capabilities

- Interconnection-Wide System Analysis
  - Frequency Response, Future Impacts of VER/DER
- Event Analysis & Blackout Investigation
  - Advanced simulation support for NERC Event Analysis
- Reliability Guidelines
  - Model validation, frequency response, load modeling, PMUs
- Emerging Technologies
  - Electric vehicles, distributed resources, storage, changing loads,
- Standards Development
  - Support advanced analytics for standards development; support industry in modifying standards to reflect technologies/capabilities
- Industry Support
  - IEEE 1547, PSRC, NASPI, NATF, NAGF, academia, etc.

NERC System Analysis Projects Underway

Let's explore how it all links together…

NERC Synchronized Measurement Subcommittee (SMS)

Purpose: *Provide input for creation and management of robust, adequate, widely available and secure synchronized data measurement exchange structures across North America.*

Key Work Tasks:

- PMU Placement Guideline
- SW Outage Recommendation 27 – Angular Separation
- Leveraging PMU Technology for Enhanced Reliability
- Power Plant Model Verification
- Interconnection-wide Oscillation Analysis

MOD-026-1 & MOD-027-1: Verification of Models and Data

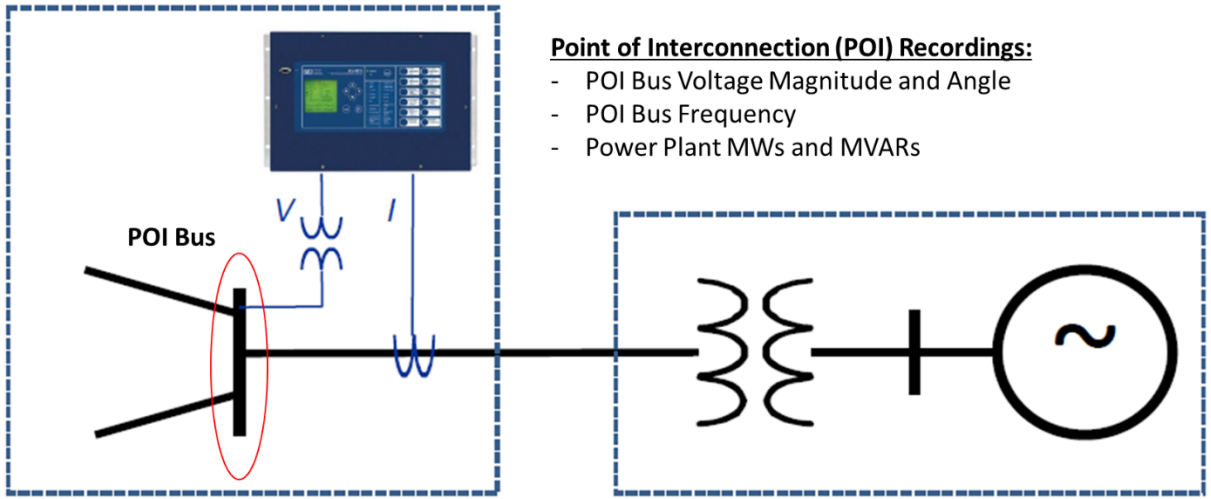
- **MOD-026:** Generator excitation control system or plant volt/var control functions
- **MOD-027:** Turbine/governor and load control or active power/frequency control functions
- Applicability:
  - Individual generating unit greater than 100 MVA gross nameplate rating
  - Individual generating plant consisting of multiple generating units that are directly connected at a common BES bus with total generation greater than 100 MVA gross aggregate nameplate rating
- Process:
  - R1. TP provides instructions and model data to GO
  - R2. GO provides verified model back to TP
  - R3. TP can provide oversight of model and performance
  - R4. GO provides revised model/plans upon any changes made

MOD-026-1 & MOD-027-1: Verification of Models and Data

- **Requirement R3:** "…receiving one of the following items for an applicable unit:"
  - "…supporting evidence from its Transmission Planner indicating that the simulated…model response did not match the recorded response to a transmission system event."

- **Requirement R5:** "Each [GO] shall provide a written response to its [TP]…following receipt of a **technically justified***…request from the [TP] to perform a model review of a unit or plant…"
  - "Corrected model data including the source of revised model data…"
  - ***technical justified**: achieved by the [TP] demonstrating that the simulated unit or plant response does not match the measured unit or plant response.

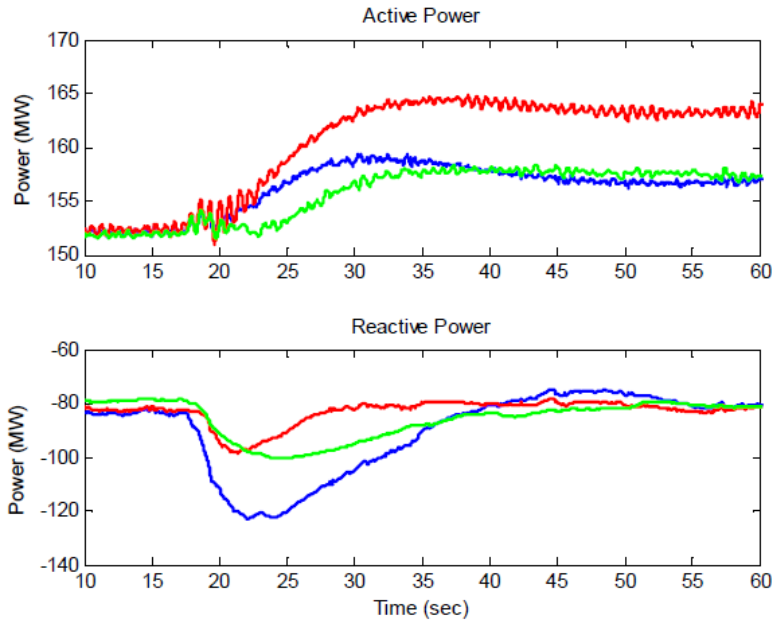
PMUs for Model Verification



Point of Interconnection (POI) Recordings:

- POI Bus Voltage Magnitude and Angle
- POI Bus Frequency
- Power Plant MWs and MVARs

Source: BPA

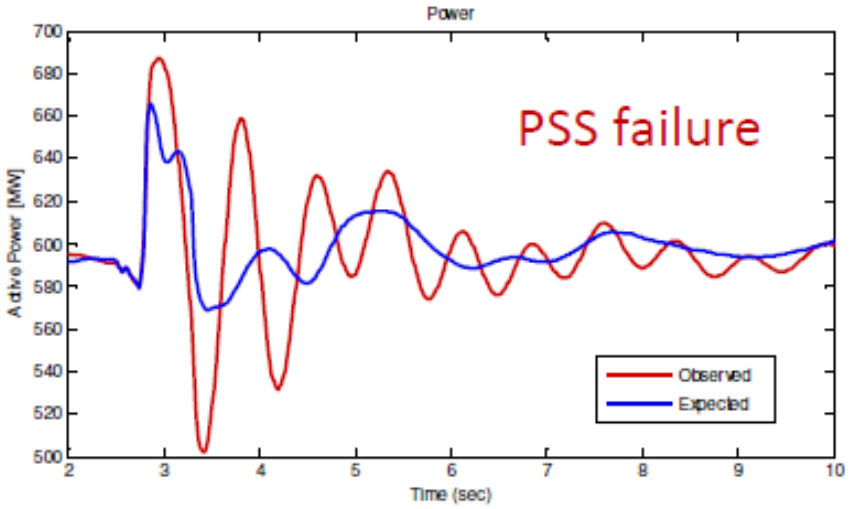


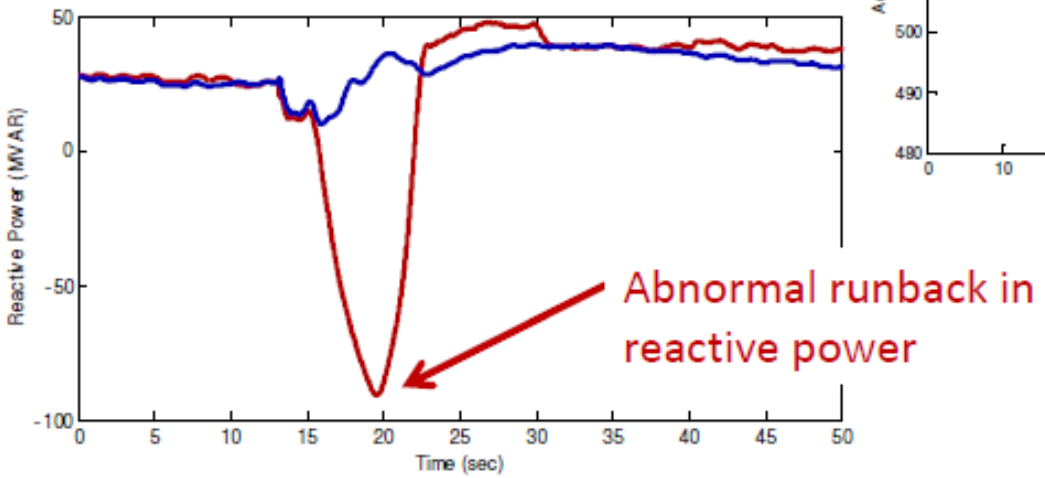
Consultant A

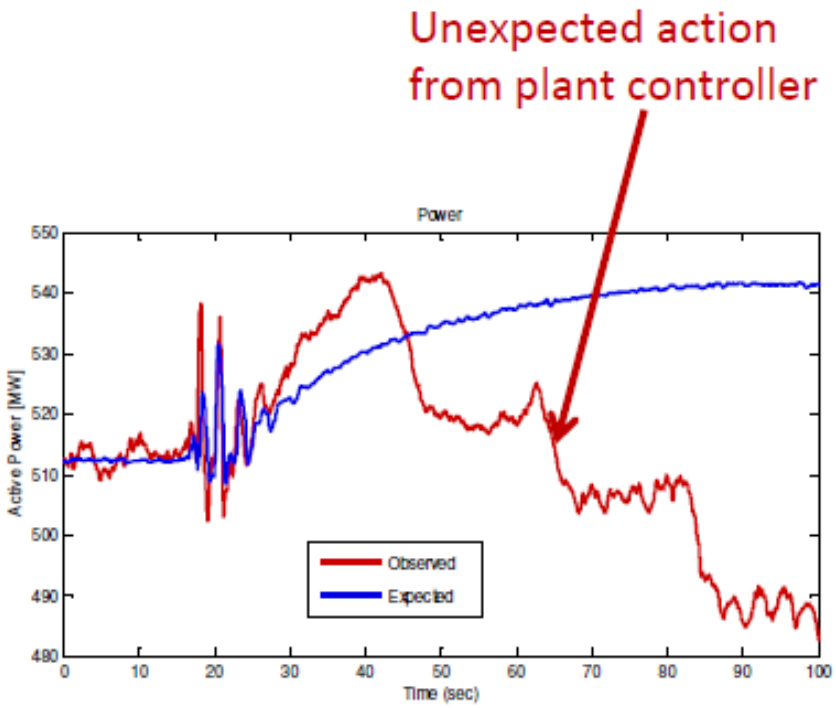
Consultant B

Reality

Beyond Model Verification: Performance Monitoring

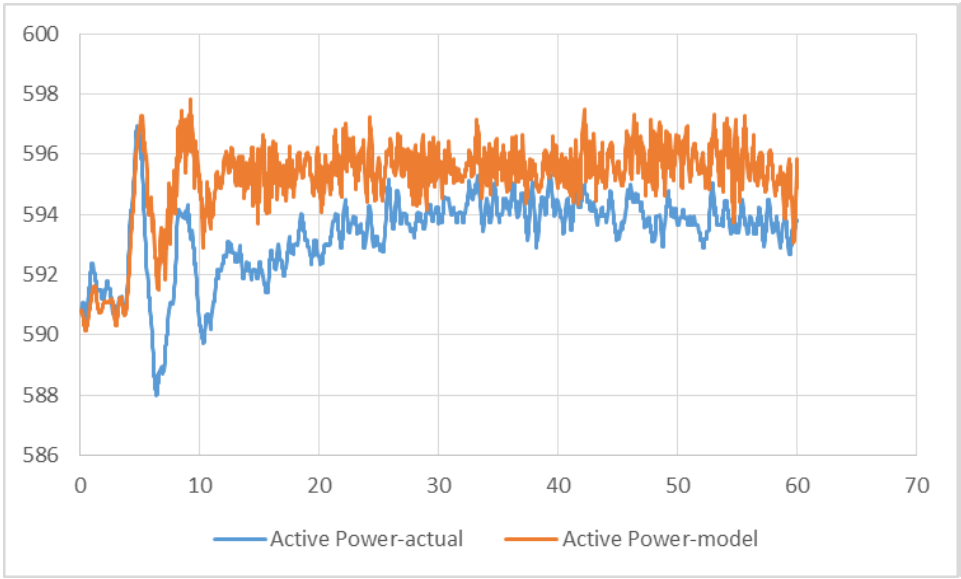




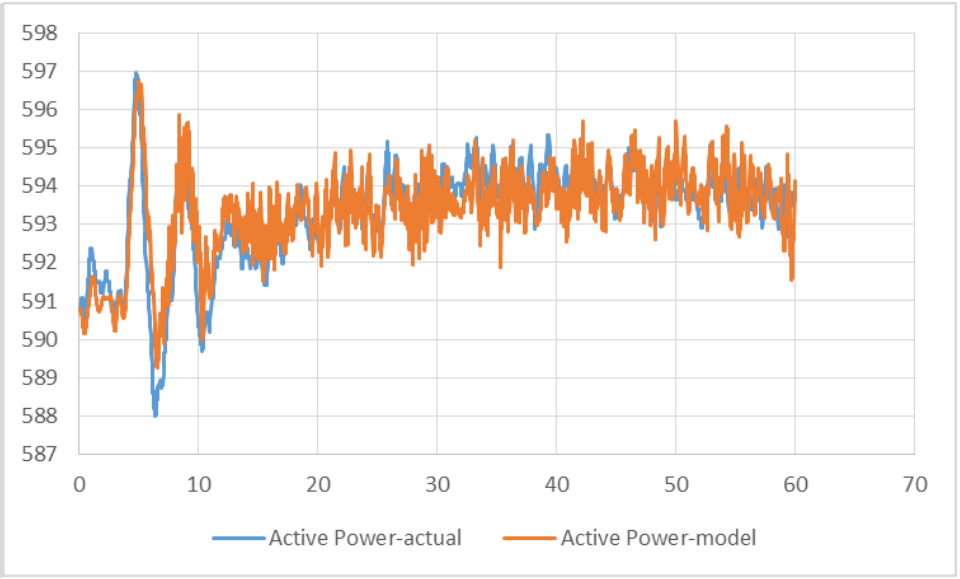


Source: BPA

Power Plant Model Verification Examples



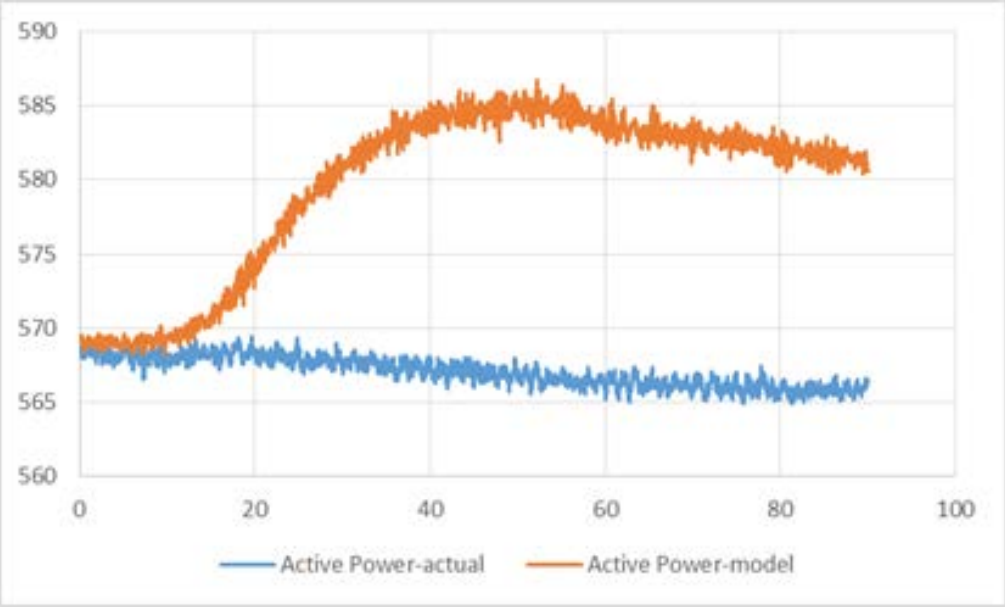
GAST Model Representation



GGOV1 Model Representation

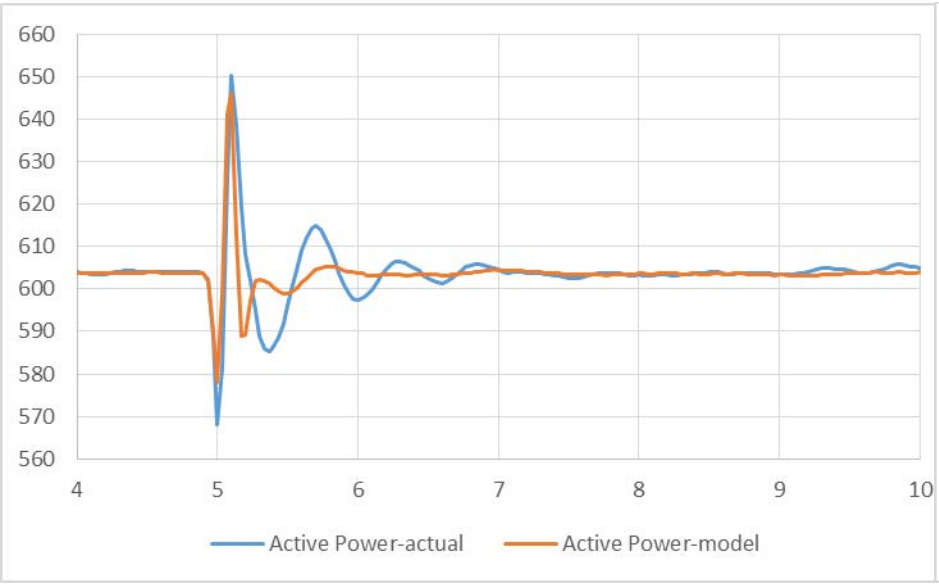
- GAST model used on new gas turbine generator (< 5 years old)
- GAST is Proportional gain model, no Integral component
- Swapped GAST for GGOV1 – generic parameters – got results above
  - 1000+ GAST models in EI base case
  - HOW do we swap those models? Industry needs guidance.

Frequency Response Issue

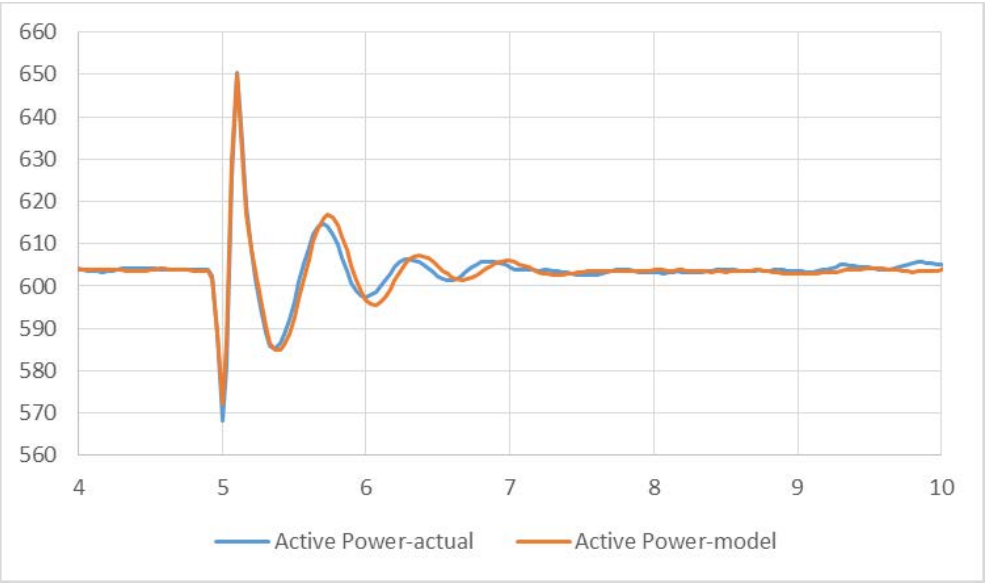


- EI base cases (off the shelf) do not match frequency response characteristic (even remotely)
  - ERAG-MMWG has developed case(s) that reflect reality using auxiliary scripts and dynamics records
- Working with Siemens PTI to get baseload flag into .raw file

PSS Gain Adjustments



PSS2B Gain = 6.0

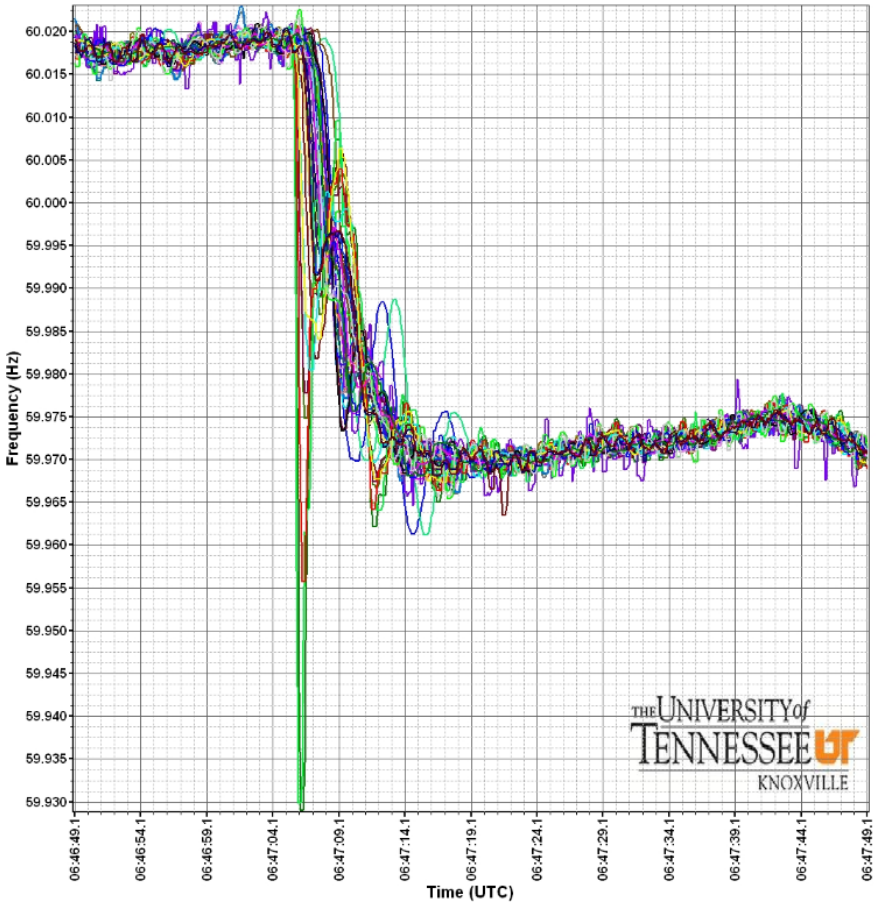


PSS2B Gain = 1.0

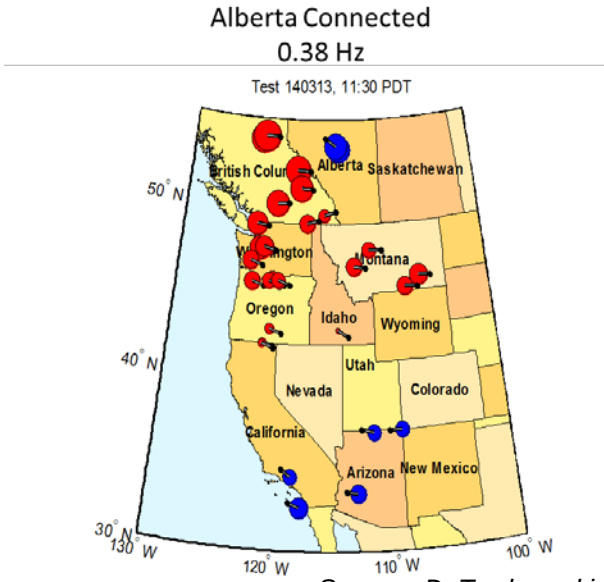
- PSS2B KS1 Gain changed
- Verifying on additional events
- We need a ‘formal’ process for making these changes. Industry needs guidance.

Special Reliability Assessment: Inter-Area Oscillation Analysis

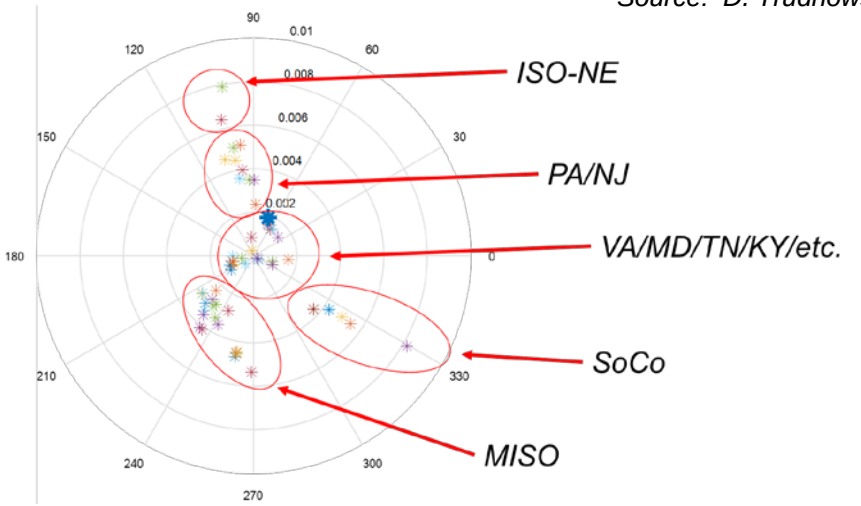
- We now have approval by NERC Planning Committee to collect interconnection-wide



Source: FNET



Source: D. Trudnowski



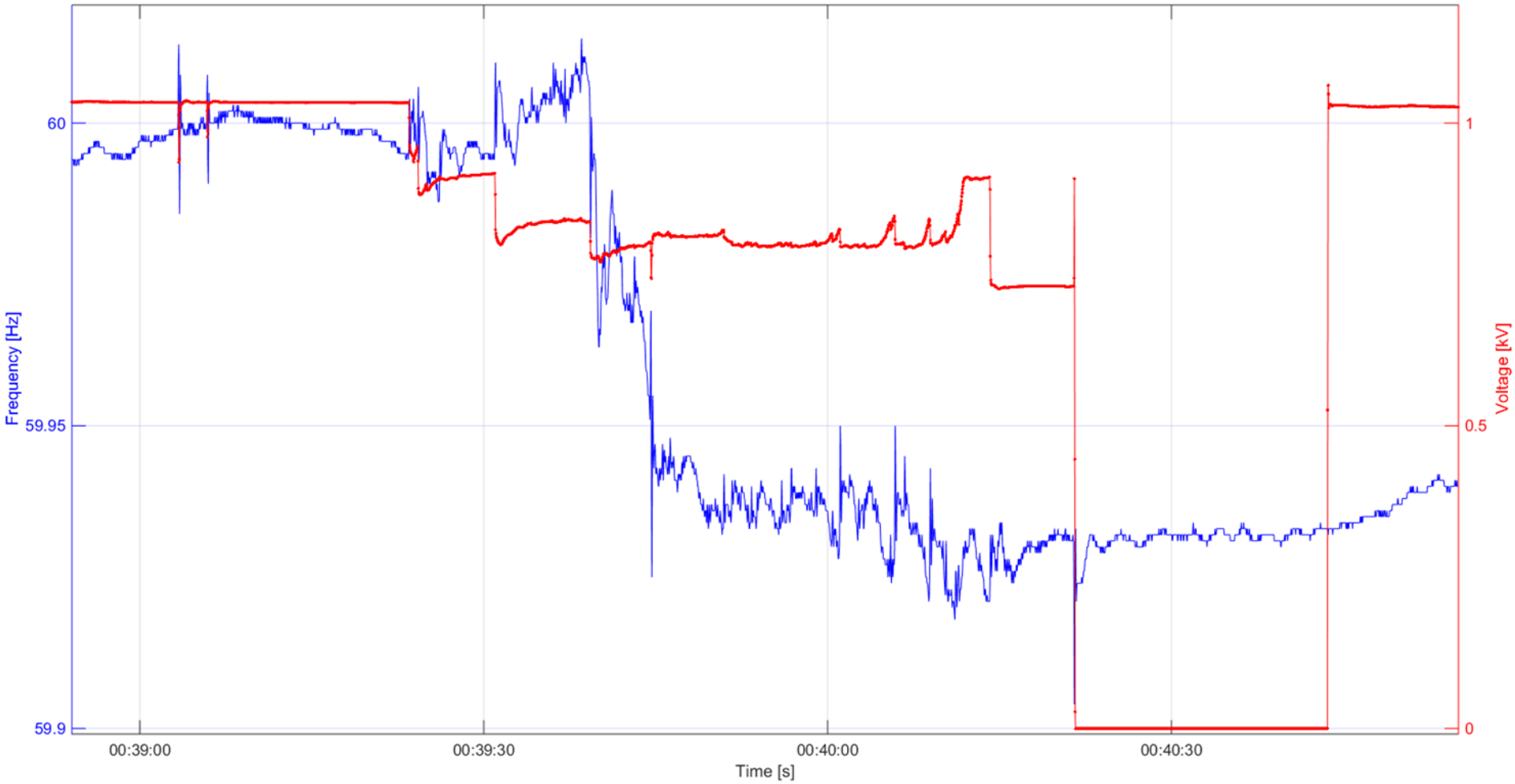
PRC-002-2: Disturbance Monitoring

Purpose: *Adequate data available to facilitate analysis of Bulk Electric System (BES) Disturbances*

- Sequence of Events & Fault Recording
  - Based on system fault MVA
- Dynamic Disturbance Recording (DDR) - PMUs
  - Generators > 500 MVA
  - Aggregate generators > 1,000 MVA
  - System Operating Limits (SOL) & Interconnection Reliability Operating Limits (IROL)
  - Voltage sensitive areas

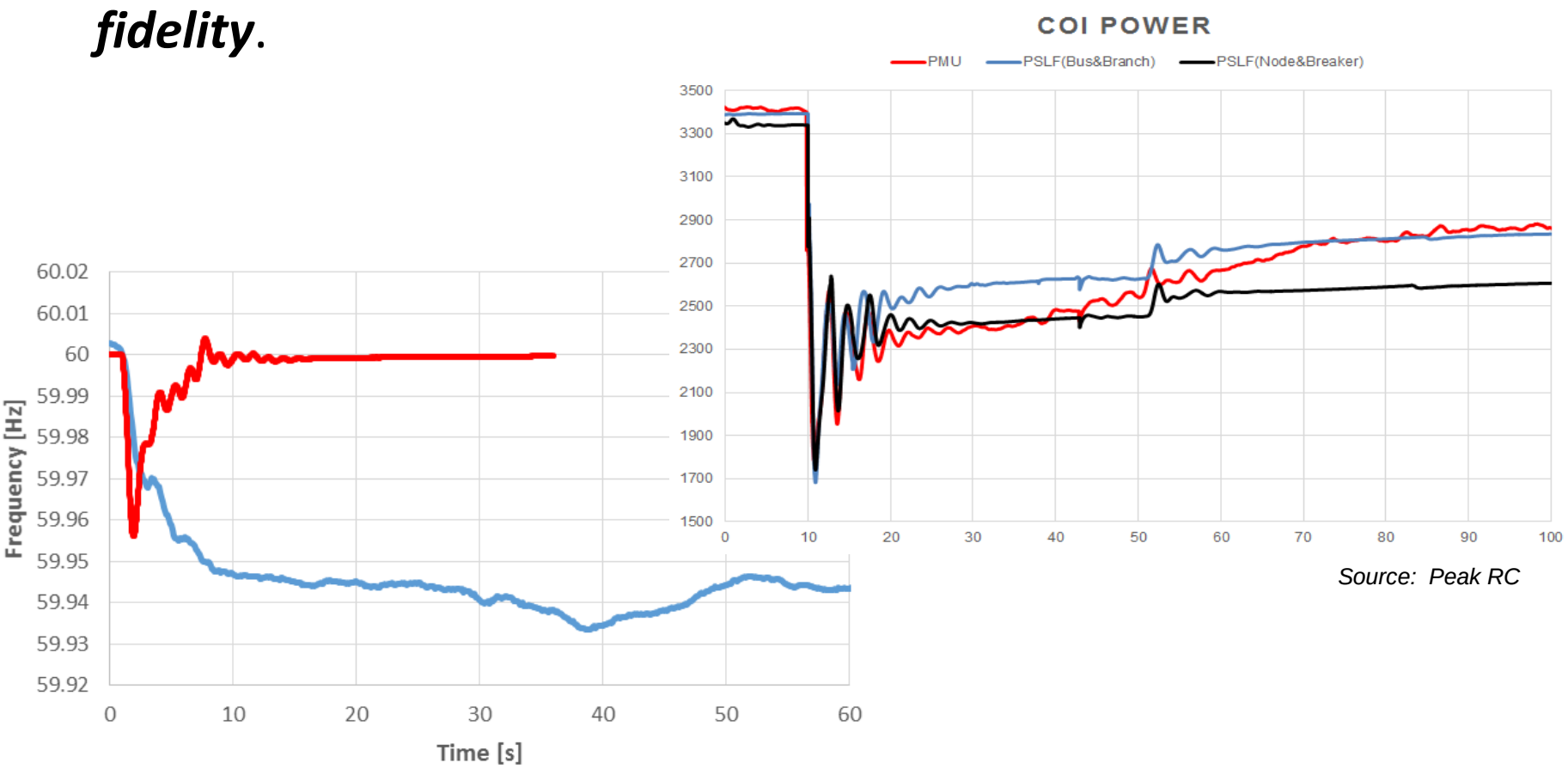
- Improved analytical capability for event analysis and advanced grid forensics

PRC-002-2: Disturbance Monitoring



MOD-033: System Model Validation

- Does the case match actual system performance? Need to perform model validation of system as a whole to ensure ***case fidelity***.



Source: Peak RC

NERC System Analysis & Modeling Subcommittee (SAMS)

Purpose: *Provide technical guidance related to topics involving Transmission Planning and modeling for North American utilities.*

Key Work Tasks:

- Reactive Power Planning Guideline
- Integrating Variable Energy Resources – Lessons Learned
- GMD Modeling Guideline
- Three-Phase Modeling Technical Reference

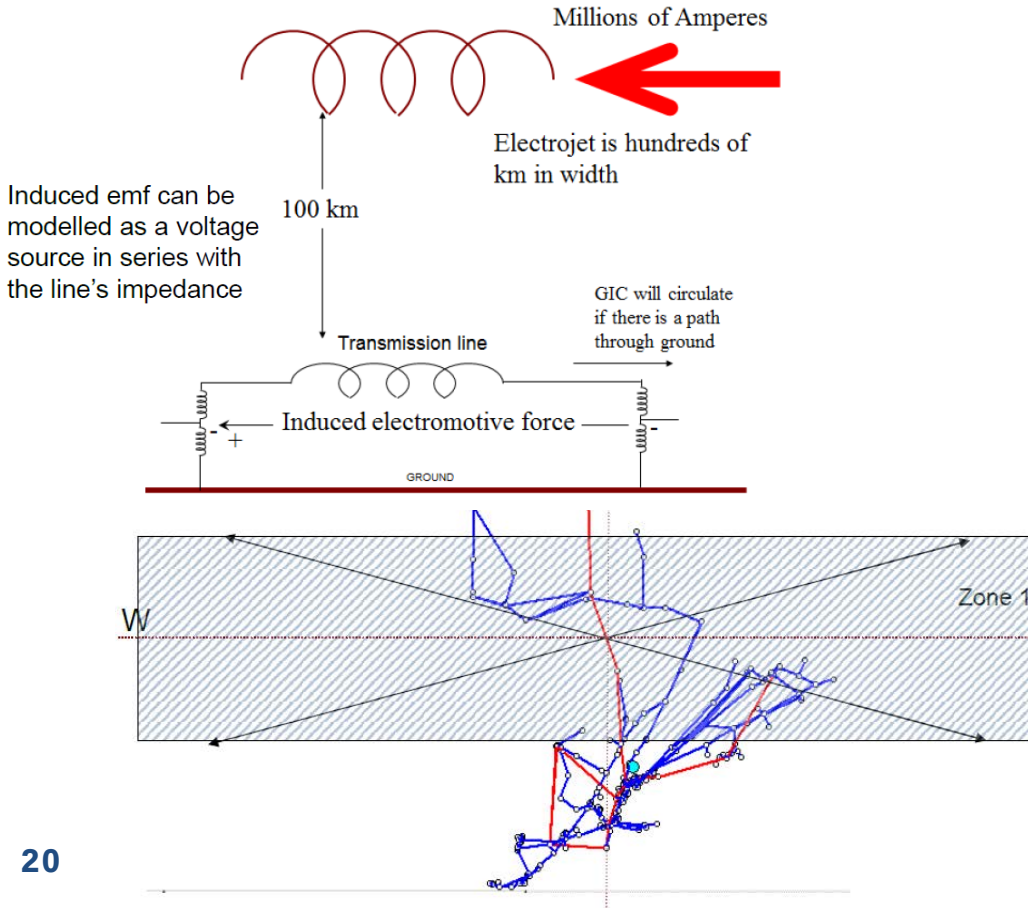
TPL-001-4: Transmission Planning

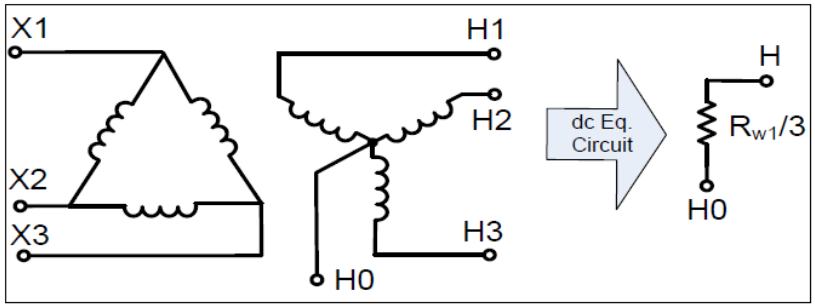
- **Purpose:** *Establish Transmission system planning performance requirements*

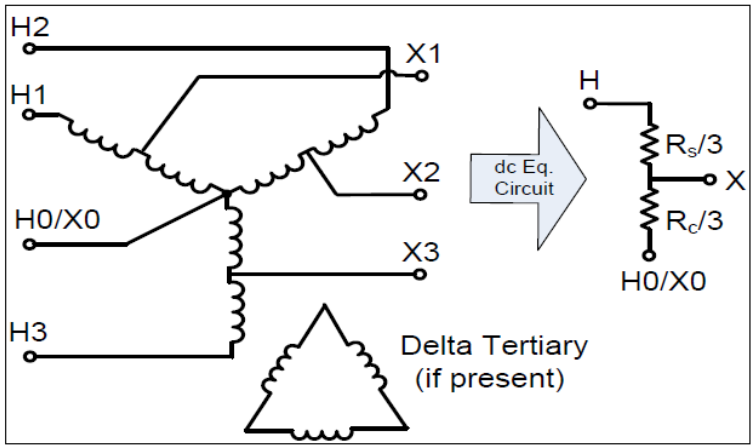
Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P3 Multiple Contingency	Loss of generator unit followed by System adjustments[9]	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single pole of a DC line	SLG			
P4 Multiple Contingency *(Fault plus stuck breaker[10])*	Normal System	Loss of multiple elements caused by a stuck breaker [10](non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
		6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	EHV, HV	Yes	Yes
P5 Multiple Contingency *(Fault plus relay failure to operate)*	Normal System	Delayed Fault Clearing due to the failure of a non-redundant relay[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
P6 Multiple Contingency *(Two overlapping singles)*	Loss of one of the following followed by System adjustments.[9] 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device[6] 4. Single pole of a DC line	Loss of one of the following: 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device [6]	3Ø	EHV, HV	Yes	Yes
		4. Single pole of a DC line	SLG	EHV, HV	Yes	Yes

TPL-007: Geomagnetic Disturbances

- **Purpose:** *Establish requirements for Transmission system planned performance during geomagnetic disturbance (GMD) events.*

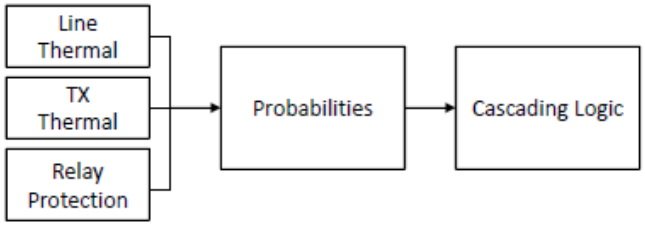


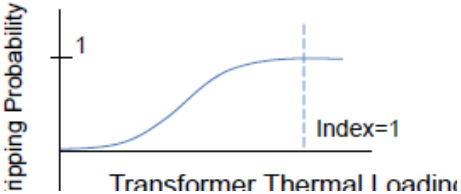


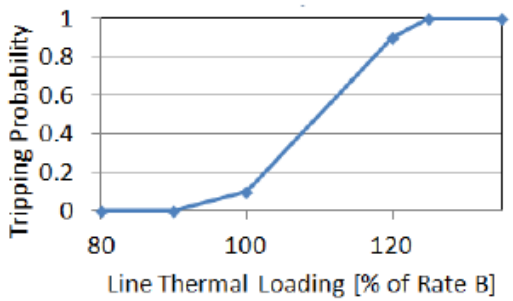


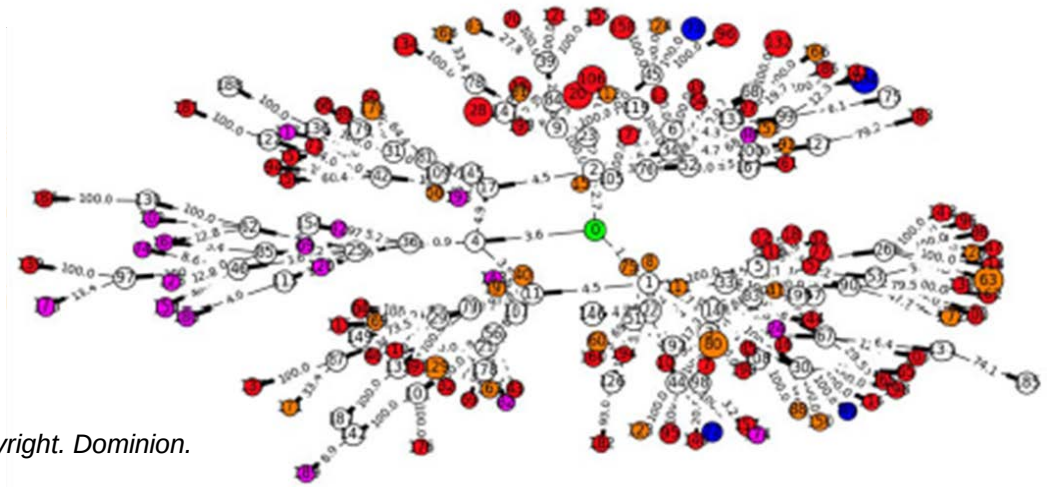
CIP-014: Physical Security

- Requirement R1: *risk assessments "to identify the Transmission station(s) and Transmission substation(s) that if rendered inoperable or damaged could result in instability, uncontrolled separation, or Cascading within an Interconnection."*









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Case Quality Metrics Assessment

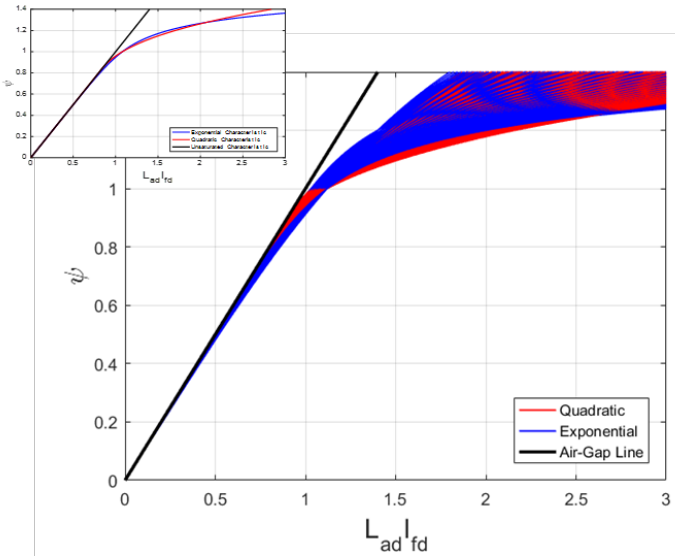
- **Case Quality:** Reasonableness of the data for individual Element models that comprise the powerflow and dynamics cases.
  - **Powerflow Metrics:** assessment of quality of powerflow base case as developed by interconnection-wide case creation entities
  - **Dynamics Metrics:** assessment of quality of associated dynamics case – component models
- **Assessments**
  - **Phase 1 (2015):** Initial development of criteria and testing; main focus on powerflow case
  - **Phase 2 (2016):** Re-assessment of Phase 1 metrics; additional metrics, focus on dynamics
  - **Phase 3 (2017):** At a minimum, assessment of Phase 1 and 2 metrics on new cases (trending); possible new metrics

Powerflow and Dynamics Metrics Phases 1 and 2

Phase	Powerflow	Dynamics
Phase 1 (2015)	• P_{max} and P_{min} violations • Scheduled interchange equality • V_{sched} conflicts • Transformer tap steps • Thermal rating consistency • Line and transformer loading	• Generator netting • Generator classical model representation • Consistence reactance values
Phase 2 (2016)	• Generator reactive dispatch at limits • Generator reactive limit power factor • Positive sequence circulating current • Load power factors • Generator impedances	• Generator inertia and time constants • Saturation factors and “severe” factors • Generator speed damping coefficient • Turbine-governor time constants • Turbine power development fractions • GAST models • DC exciter self-excitation parameters • WT3E electrical wind wind speeds

Metrics Assessment Observations

- P_{max} and P_{min} Violations
- Generator Reactive Limits
- Generator Reactive Limits Power Factor
- Generator Time Constants
- Generator Inertia Constants
- Saturation Factors
- Speed Damping Coefficient
- Turbine-Governor Power Development Fractions
- GAST Model
- Self-Excitation Parameter for DC Exciters



NERC Modeling Working Group (MWG)

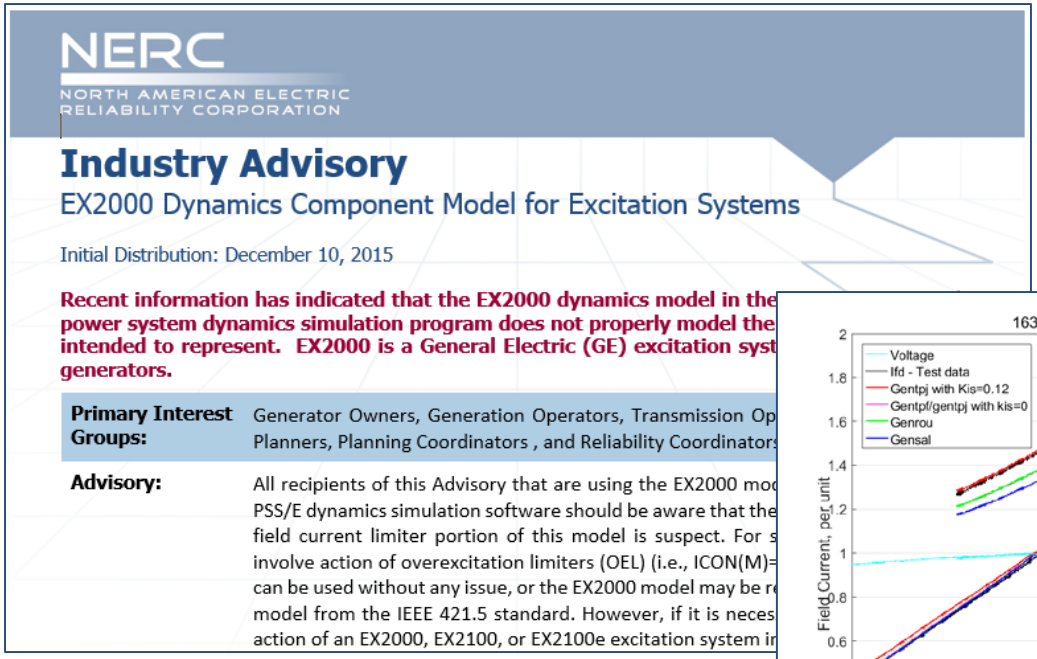
Purpose: *Promote development and use of accurate system and electric equipment models for steady state and dynamic simulations*

Key Work Tasks:

- Modeling Notifications
- Standardized Component Models
- Breaker-Node Representation

Modeling Notifications

- **Focus:** Interconnection-wide awareness of modeling issues or advancements deemed necessary by modeling experts.
  - Ex. Case quality assessment, power plant model verification, stability studies
- Examples
  - EX2000
  - GENSAL
  - GAST
  - **What's Next?**
  - **Priority?**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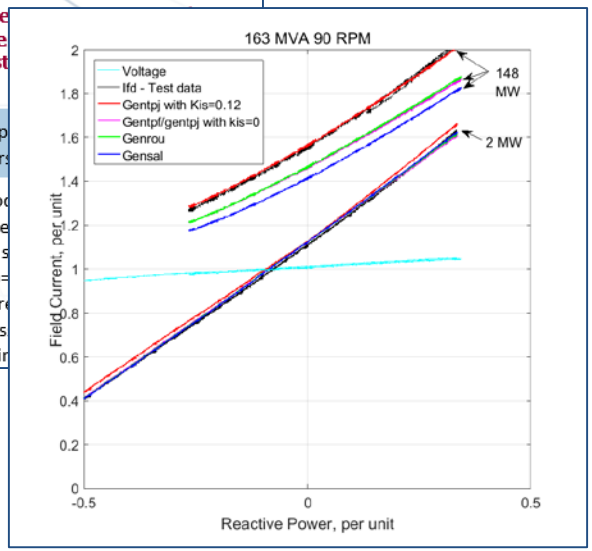
Industry Advisory

EX2000 Dynamics Component Model for Excitation Systems

Initial Distribution: December 10, 2015

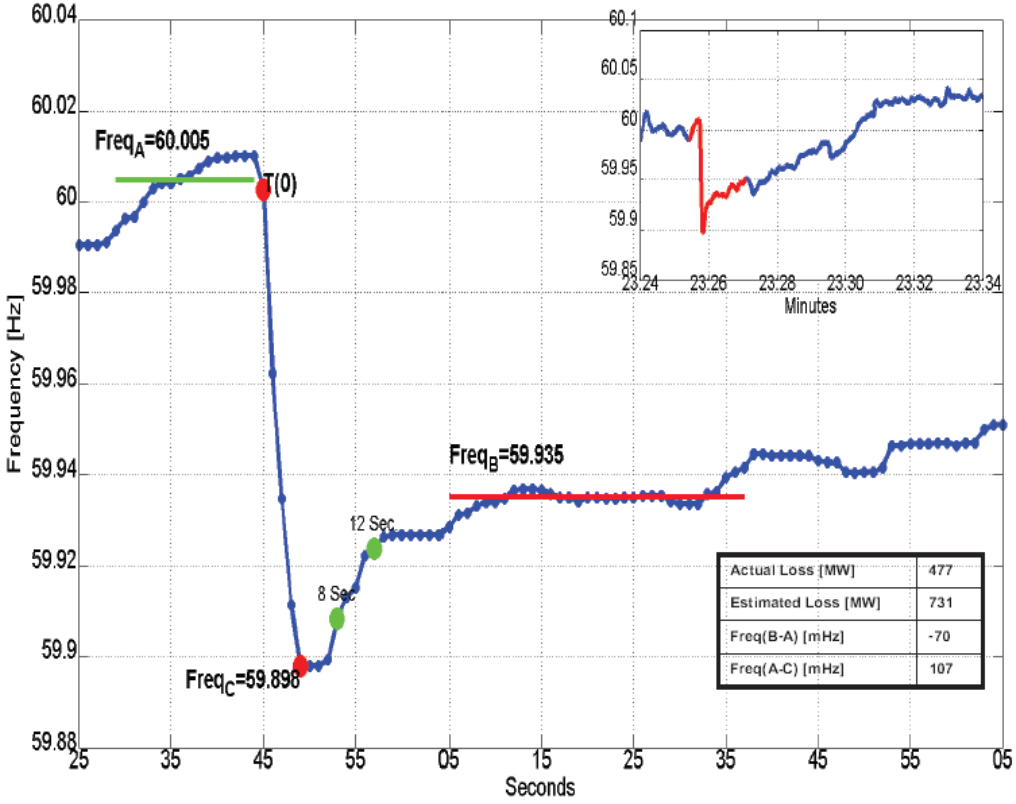
Recent information has indicated that the EX2000 dynamics model in the power system dynamics simulation program does not properly model the intended to represent. EX2000 is a General Electric (GE) excitation syst generators.

Primary Interest Groups:	Generator Owners, Generation Operators, Transmission Op Planners, Planning Coordinators , and Reliability Coordinators
Advisory:	All recipients of this Advisory that are using the EX2000 mod PSS/E dynamics simulation software should be aware that the field current limiter portion of this model is suspect. For s involve action of overexcitation limiters (OEL) (i.e., ICON(M)= can be used without any issue, or the EX2000 model may be re model from the IEEE 421.5 standard. However, if it is neces action of an EX2000, EX2100, or EX2100e excitation system in



NERC Resources Subcommittee (RS) & Frequency Working Group (FWG)

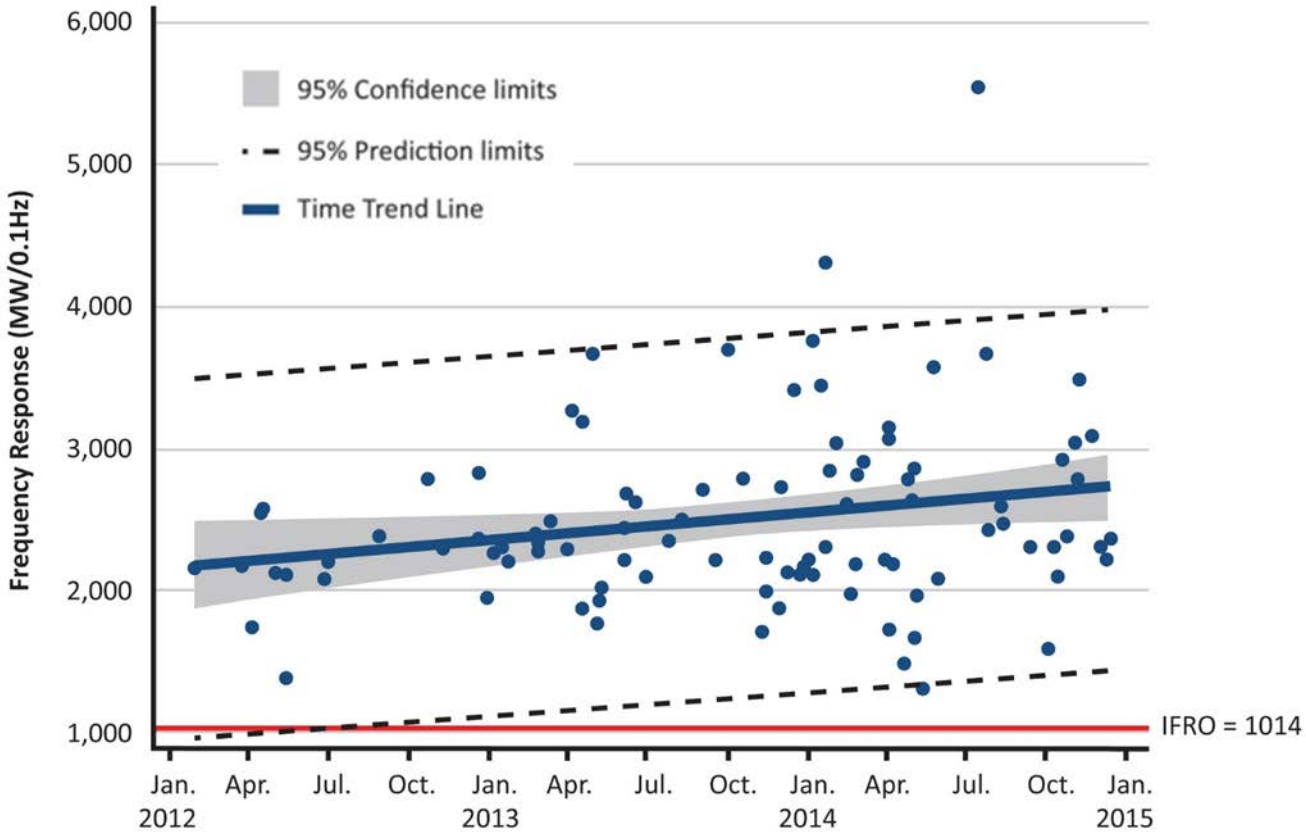
- NERC RS and FWG – clearinghouse for frequency control
  - Primary Frequency Response
  - Governor Response
  - Secondary Response
  - AGC Coordination
  - Frequency Bias Settings
  - Time Error Correction
  - Inadvertent Interchanges



- FWG selects system events for M4 (trending) and BAL-003 (standards compliance)

BAL-003: Frequency Response & Bias Setting

- **Purpose:** Require sufficient Frequency Response from BAs to maintain Interconnection Frequency within predefined bounds



Frequency Response Analysis Tool (FRAT)

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Database of events

Event Plot

Interconnection/BA M...

Events DataBase

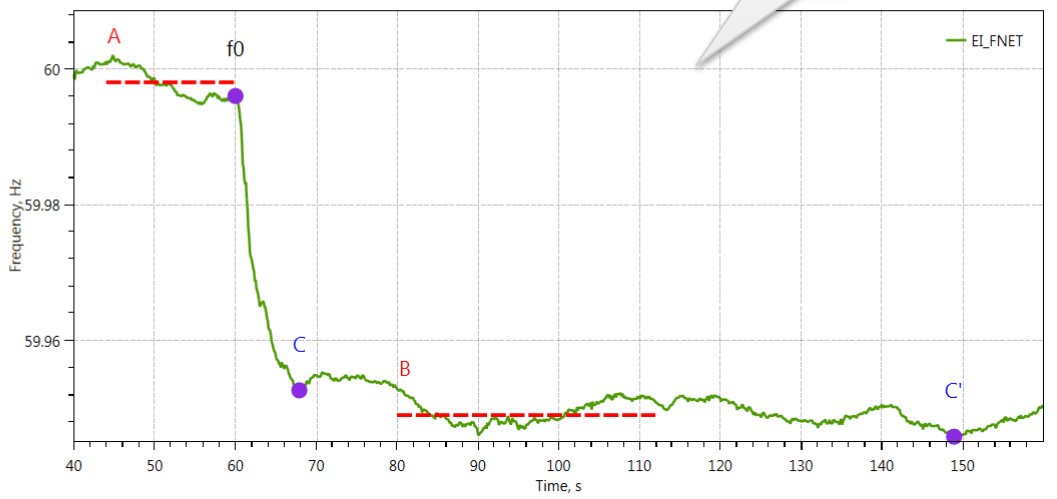
Event Name	Date	Time	Disturban	RM NERC	FRM BA
20120113-200257E	01/13/12	20:02:57	524	1455.556	0
20120130-160157E	01/30/12	16:01:57	1152	2504.348	0
20120302-195319E	03/02/12	19:53:19	1300	1884.058	0
20120323-182826E	03/23/12	18:28:26	1228	2117.241	0
20120414-174650E	04/14/12	17:46:50	1800	2535.211	0
20120430-140241E	04/30/12	14:02:41	1237	2132.759	0
20120504-173404E	05/04/12	17:34:04	1300	2363.636	0
20120521-195215E	05/21/12	19:52:15	903	2052.273	0
20120626-175002E	06/26/12	17:50:02	1320	2062.5	0
20120702-025225E	07/02/12	02:52:25	1200	2142.857	0
20120803-124122E	08/03/12	12:41:22	1186	3488.235	0
20120828-073034E	08/28/12	07:30:34	1150	2346.939	0
20120909-145954E	09/09/12	14:59:54	540	1285.714	0
20120915-055418E	09/15/12	05:54:18	694	1285.185	0
20120922-193805E	09/22/12	19:38:05	189	460.976	0
20121023-222807E	10/23/12	22:28:07	1234	2742.222	0
20121030-050928E	10/30/12	05:09:28	0	0	0
20121109-061752E	11/09/12	06:17:52	1165	2284.314	0
20121111-085431E	11/11/12	08:54:31	1013	2110.417	0
20121229-061816E	12/29/12	06:18:16	1300	1940.299	0

Event Plot

SubPlots
- Frequency
- Active Power
- Voltage
- Reactive Power

Performance Points
- NERC
- F0
- FC
- Fsettling
- F20/30/60/90

Legend
- EIFNET
- Mean Freq



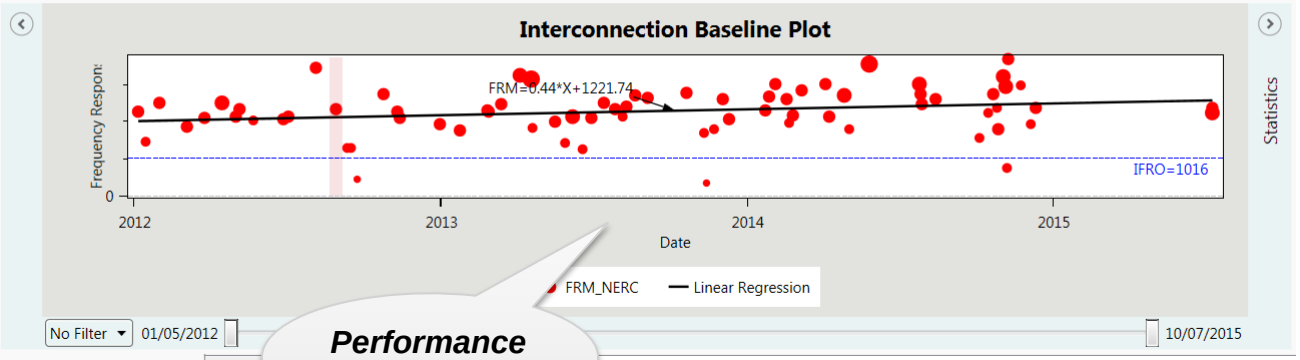
Event Characteristics

- Event Description
- Load/Generation
- Time/Frequency
- NERC Performance

Interconnection		Balancing Authority	
FA NERC	59.998	PA Interchange	0
FB NERC	59.949	PB Interchange	0
FC NERC	59.953	FRM BA	0
FC' NERC	59.946	PA Generation	0
FRM NERC	2346.939	PB Generation	0
		FR Gen BA	0

- Additional Performance Indexes

Interconnection Baseline Plot



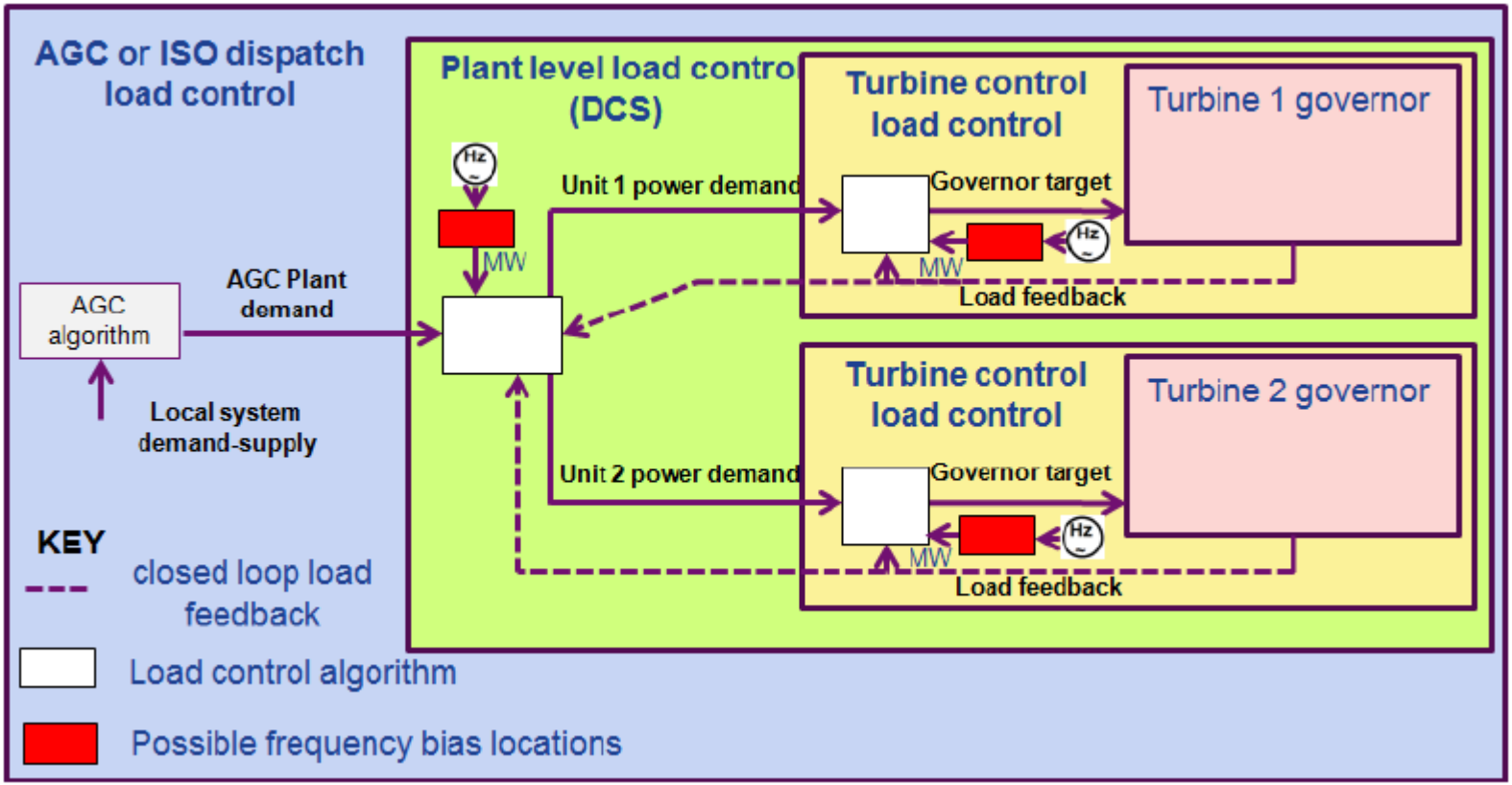
Interconnection Baseline Plot | BA Base...

Event Details

Performance Baseline

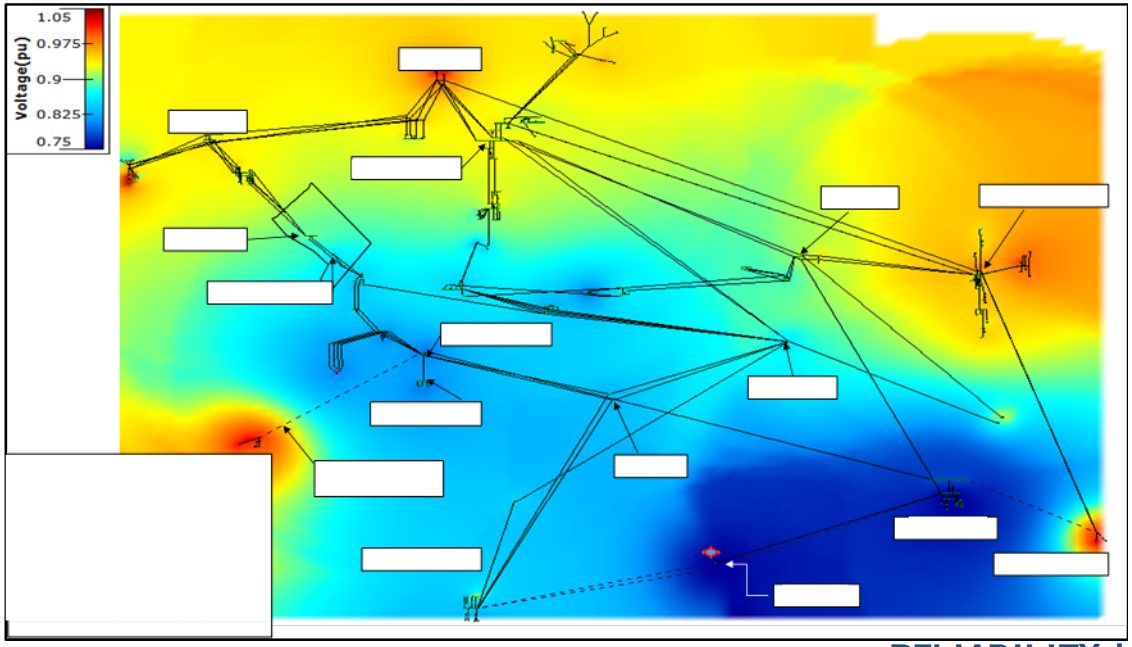
Primary Frequency Response Guideline

- Strategy for Primary Frequency Control during deviation events
- Recommended governor deadband and droop settings
- Understanding plant-level load control impacts



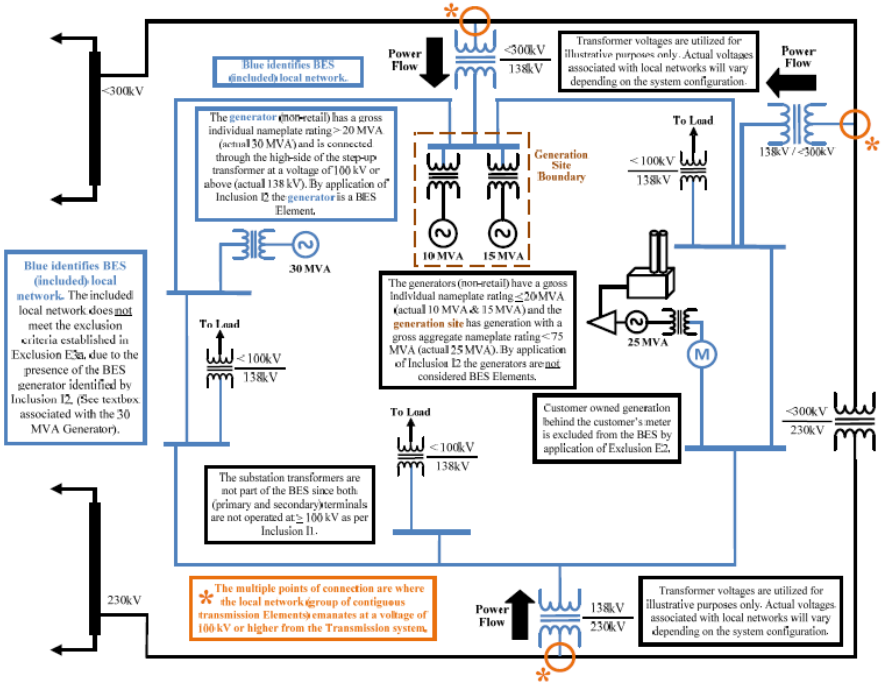
Major Disturbances: Investigation & System Analysis

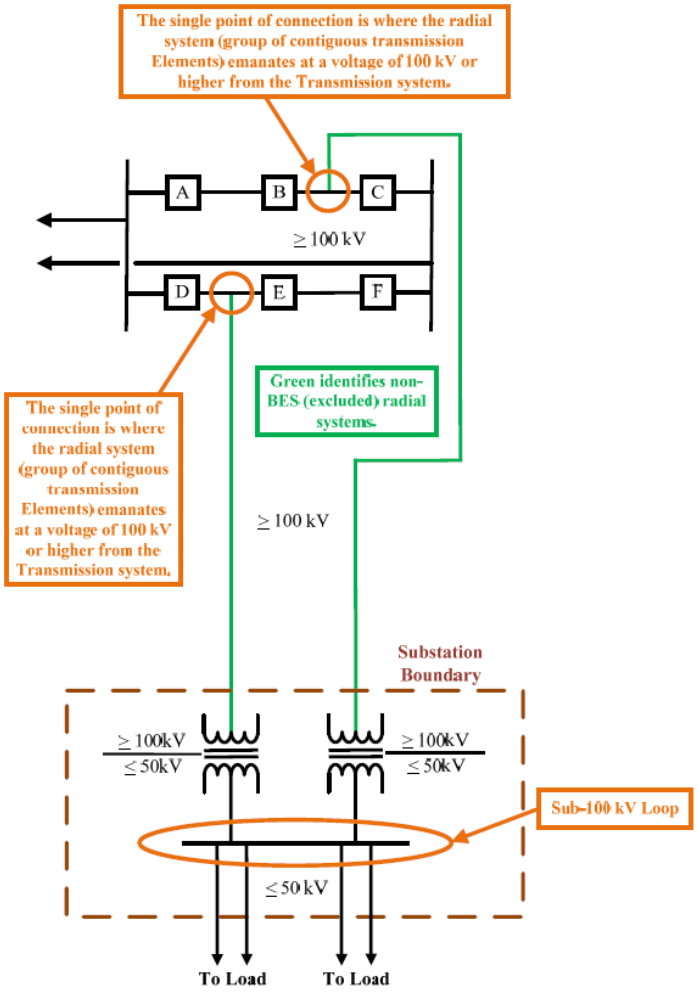
- System Analysis supports NERC Event Analysis for major grid events, particularly regarding simulations and modeling
- Recreate affected region in powerflow case
- Simulate sequence of events to validate event details
- Used for root cause analysis and sequence of events alignment



Bulk Electric System (BES) Processing

- **BES:** All Elements and Facilities necessary for the reliable operation and planning the interconnected Bulk-Power System
  - Self-Determined Notifications
  - Exception Requests





Essential Reliability Services (ERSWG)

- Purpose: ensure essential reliability services as electric grid rapidly continues to change (renewables, retirements, etc.)
- Goal: develop measures to trend ERS moving forward and looking backward – develop guidance material accordingly
  - Measure 1 – Synchronous Inertial trend (Interconnection)
  - Measure 2 – Initial Frequency Deviation following largest contingency
  - Measure 3 – Synchronous Inertial trend (BA)
  - Measure 4 – Frequency Response
  - Measure 6 – Net Load Ramping Variability
  - Measure 7 – System Reactive Capability
  - Measure 10 – Short Circuit Strength

NERC Plant-Level Controls & Protection Modeling Task Force (PCPMTF)

- Power plant modeling is limited to major Elements in plant
  - Generator, Turbine-Governor, Excitation, PSS, Limiters, Etc.
- More complex models either don't exist or are not being implemented in standard cases
- This TF is looking at what plant-level controls & protection are impacting unit performance and whether or not we have modeling capability in commercial software programs
  - This is incredibly valuable for forensic event analysis
- Examples:
  - Power Load Unbalance (PLU) relaying
  - Auxiliary bus undervoltage relaying & dropouts
  - Plant Distributed Control System (DCS) Load Controls
  - Boiler-pressure control vs. governor control

Closing Remarks

- NERC advancing its analytical capabilities
  - System Modeling Improvements
  - Reliability Assessments
  - System Studies & Analysis
  - Event Analysis & Forensics
  - Industry Support & Outreach
- NERC interested in supporting academic community
  - Communicate current and emerging reliability needs
  - Support R&D initiatives and projects
  - Work with academic community to publish valuable/relevant findings
  - Engage in relevant NERC technical subcommittees
  - Provide networking mechanism to get students engaged in industry

Questions and Answers

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International Council on Large Electric Systems

- CIGRE: International Council on Large Electric Systems
- CIGRE US National Committee (USNC)
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    - GOTF Paper Competition
      - Top papers submitted to CIGRE Paris Session
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B5	Protection and Automation
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C3	System Environmental Performance
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